Solution

ENGINEERING PHYSICS 4D3/6D3

DAY CLASS — Dr. Wm. Garland

DURATION: 20 minutes

McMASTER UNIVERSITY QUIZ #2 — November 22, 2004

Special Instructions: Closed Book. All calculators and up to 6 single sided 8 ½" by 11" crib sheets are permitted.

THIS EXAMINATION PAPER INCLUDES 1 PAGE AND 1 QUESTION.

1. For the 2 group neutron diffusion equations in transient form, not ignoring the delayed precursors:
   a. [10 marks] Write out the neutron diffusion and precursor equations for a general geometry.
   b. [5 marks] Which term(s) are the effective source terms for the thermal neutrons?
   c. [5 marks] Which term(s) are the effective source terms for the fast neutrons?
   d. [10 marks] Why can we safely ignore upscatter?
   e. [10 marks] Which terms are the ones most affected by fission product poisons?
   f. [10 marks] In the steady state, show how we can safely ignore the delayed precursors in the neutron equation, stating any assumptions made.

(a)
$$\frac{1}{v_1}\frac{\partial \phi_1}{\partial t} = \nabla\cdot D_1\nabla\phi_1 - \Sigma_{a_1}\phi_1 - \Sigma_{s_1}\phi_1 + \Sigma_{s_{11}}\phi_1 + \cancel{\Sigma_{s_{21}}\phi_2}$$ no upscatter

$$\underbrace{+\underbrace{\chi_1^P}_{\simeq 1}(1-\beta)\left[\nu_1\Sigma_{f_1}\phi_1 + \nu_2\Sigma_{f_2}\phi_2\right]}_{\text{small}}\ (2) + S_1 + \underbrace{\chi_1^C}_{\simeq 1}\sum_{i=1}^{N}\lambda_i C_i \ (3)$$

all terms are functions of r & t

$$\frac{1}{v_2}\frac{\partial\phi_2}{\partial t} = \nabla\cdot D_2\nabla\phi_2 - \Sigma_{a_2}\phi_2 - \cancel{\Sigma_{s_2}\phi_2} + \Sigma_{s_{12}}\phi_1\ (1) + \cancel{\Sigma_{s_{22}}\phi_2}$$

$$+ \underbrace{\chi_2^P}_{\simeq 0}(1-\beta)\left[\nu_1\Sigma_{f_1}\phi_1 + \nu_2\Sigma_{f_2}\phi_2\right] + \underbrace{\cancel{S_2}}_{0} + \underbrace{\chi_2^C}_{\simeq 0}\sum_{i=1}^{N}\lambda_i C_i$$

$$\Sigma_{s_2} = \underbrace{\cancel{\Sigma_{s_{21}}}}_{0} + \Sigma_{s_{22}} \Rightarrow \Sigma_{s_2} = \Sigma_{s_{22}}$$

$$\frac{\partial C_i}{\partial t} = -\lambda_i C_i + \beta_i\left[\nu_1\Sigma_{f_1}\phi_1 + \nu_2\Sigma_{f_2}\phi_2\right]$$

(b) For Group 2 (thermals), the term marked (1) above is the effective source term (slowing down from fast). $\chi_2 \simeq 0$ since neutrons are born in fast region.

(c) For Group 1 (fast), the term marked (2) above is the effective source term. Plus (3)

(d) Can ignore upscatter ($\Sigma_{s_{21}}$) because energy separation is too great for appreciable upscatter.

...use other side if needed

(e) The poisons affect the Σ_a terms primarily and the changes in Σ_{a2} is the more significant one since it is the more significant Σ_a.
X_e has a large thermal Σ_a.

(f) In steady state:

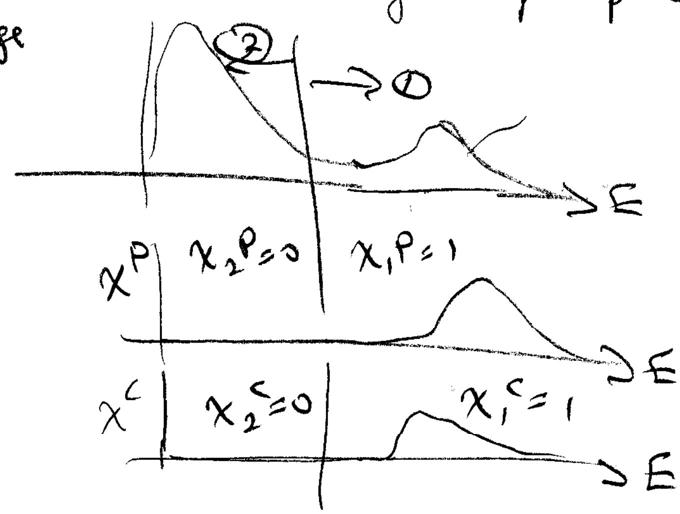
$$\frac{\partial C_i}{\partial t} = 0 \Rightarrow \lambda_i C_i = \beta_i \left[\nu_1 \Sigma_{f_1} \phi_1 + \nu_2 \Sigma_{f_2} \phi_2\right]$$

$$\therefore \sum_{i=1}^{N} \lambda_i C_i = \beta\left[\nu_1 \Sigma_{f_1} \phi_1 + \nu_2 \Sigma_{f_2} \phi_2\right] \text{ since } \beta = \sum_{i=1}^{N} \beta_i$$

$$\therefore \frac{1}{v_1}\frac{\partial \phi_1}{\partial t} = 0 = \nabla \cdot D_1 \nabla \phi_1 + \cdots\cdots \chi_1^P (1-\beta)\left[\nu_1 \Sigma_{f_1} \phi_1 + \nu_2 \Sigma_{f_2} \phi_2\right] + \chi_1^C \beta\left[\quad '' \quad\right]$$

The β portions will cancel only if $\chi_1^P = \chi_1^C$.

For a 2-Group approximation, this is true because the fast group is so large



For Group 2, $\chi_2^C = \chi_2^P = 0$ so the β terms are out anyway.